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Abstract

Athletes' times in 200 m indoor races are greater than in outdoor races. The purpose of this study was to determine which 50 m sections were slower indoors than outdoors in 200 m sprint events and by how much. Using two-dimensional photogrammetric techniques, a 50 m split-time analysis was made of the performance of 17 men and 16 women, all well-trained athletes, at four national competitions held over 5 years. The time taken to run the 0-50 m section was longer indoors than outdoors in women (6.89 ± 0.12 s vs. 6.75 ± 0.04 s; $P < 0.05$) and in men (6.18 ± 0.10 s vs. 6.08 ± 0.09 s; $P < 0.05$). Similarly, both women and men took more time to run the 100-150 m section indoors (6.03 ± 0.15 s vs. 5.84 ± 0.06 s, $P < 0.01$, respectively) than outdoors (5.26 ± 0.15 s vs. 5.06 ± 0.07 s, $P < 0.01$, respectively). Both sections indoors were run mostly on the curve. However, significant differences were not found in the split times for 50-100 and 150-200 m in either sex. In both categories, the relative average velocity (RAV), percentage of average velocity relative to the maximum velocity reached in the fastest section (50-100 m), was about 3% lower indoors than outdoors in 100-150m section. The athletes' lower capacity to develop speed indoors could be caused specifically, by the curved 0-50 m and 100-150 m sections of the indoor track. Coaches could use these data as reference values there being few published data from high-level competitions. The RAV could be used by coaches to compare results among athletes of different levels and sexes.

Keywords

Athletes – Track and field – Athletic Performance – Speed running – Split time –

Kinematics.

INTRODUCTION

Sprint running events have been studied in the scientific literature from a split-time point of view with the aim of improving athletes' performance by designing individual competitive strategies (1,4,12). Athletes' times in 200 m indoor races are greater than in outdoor races, although the distances covered on outdoor and indoor tracks are practically equal. Confirmation of this can be seen when comparing indoor and outdoor all-time top lists (8), where the indoor 200 m world record is equivalent to the 60th ranked time in the all-time top list of outdoor 200 m events. The different conditions in which the events are run could be the reason why different times are taken to cover the same distance. Although both indoor and outdoor tracks have curves and straights their distribution is different. Approximately, the first 100 m outdoors are on the curve and the second 100 m are on the straight. Indoors there are alternate sections of approximately 50 m of curve and straight, and the start is on a curve. Although the proportion of curve to straight may be similar in both modalities, the radii of the curves on indoor tracks are smaller than those on outdoor facilities. This difference in the radii has been postulated as one of the possible causes of the slower times recorded for the indoor 200 m (13,15,17).

Different authors described how the maximum velocity attained by an athlete was significantly slower on a curved plane than in a straight line (15). Jain (9) examined the records of several outdoor competitions and found that the runners in the 200 m were 0.4 s slower on the curve than on the straight. Other authors proposed that this slower velocity was caused by the smaller radius of the curve (3,14). Among the possible reasons for this decrease in velocity we could indicate the different ways athletes use to accelerate their centers of mass in a straight line and round a curve. Although external gravitational forces, aerodynamics and ground reaction forces (GRF) condition acceleration, it is the latter that mainly determine running speed. To reach a faster top running speed the athlete has to produce a high average vertical GRF with a short contact time (7,18). Around a curved trajectory, the athletes must generate GRF to overcome gravity and must transform part of the vertical GRF into mediolateral GRF; if they are unable to do so, velocity will decrease (16,17,18). Furthermore, the velocity reached on the curve not only depends on the internal force generated by the athlete, but also on biomechanical aspects like the difficulty in aligning the resulting GRF with the longitudinal mechanical axis of the contact leg when running (3). This alignment generally favors a reduction in the force necessary to stabilize the joints, producing greater muscle force, and increasing the metabolic cost associated with the movement (2).

All the above seems to suggest that the curved sections have more influence than the straight sections on the time of the races. An analysis of the two venues could determine which indoor sections are slower compared to outdoor sections and by how much. No study has been found which has compared 200 m outdoor and indoor track times by analyzing their differences section by section. Further, no studies have conducted a split-time analysis of competition in the 200 m indoors although this event is still run in important international competitions like the *Visa Championships Series* in the United States, the *BW-Bank Meeting* in Germany, the *Norwich Union Indoor* in the United Kingdom or the *Russian Winter*. Therefore, the aim of this study was to carry out a split-time analysis of the races of well-trained athletes competing in 200 m indoor and outdoor sprint events in order to show athletes and coaches which sections are crucial in the 200 m indoor and so that they can improve their training strategy.

METHODS

Experimental Approach to the Problem

This was a cross-sectional comparative study of running performance during the 200 m sprint event between indoor and outdoor venues. All the analyses were made of the 200 m finals in national championships. An independent sample t-test was used to investigate if there were significant differences between the 50 m sections into which the race can be divided. The dependent variables included interval times and velocities for each section, as well as the percentage reduction in velocity in each section compared to the fastest section. It was hypothesized that only the indoor curved sections were slower than the corresponding outdoor sections both for women and men.

Subjects

An analysis was made of the 200 m finals (women's and men's) in the four most important Spanish championships held over a period of five years: two outdoor and two indoor. The participants in the study were 17 men and 16 women, all well trained athletes from the senior category, who had qualified for the finals in the respective championships. In total 24 races were analyzed for each category. Of the 16 women, 4 ran once outdoors and once indoors, 2 ran twice indoors, 1 ran once outdoors and twice indoors, and the rest only ran once on one type of track, 7 outdoors and 2 indoors. Of the 17 men, 2 of them ran once outdoors and once indoors, 1 ran twice outdoors and once indoors, 1 ran once outdoors and twice indoors, I ran twice indoors and the rest ran on only once on one type of track, 7 outdoors and 5 indoors. The participants read and signed statements of informed consent before participating in the study, and the Research Ethics Committee gave prior approval for the study. Formal authorization from the Spanish Royal Athletics Federation was obtained to video record all the championships.

Procedures

Five synchronized SVHS 50 Hz video cameras (*Panasonic NV-MS4E and Panasonic S-VHS AG-DP800HEG*) were used to record the races. The video cameras were situated perpendicularly to the athletics track in order to record the time each of the athletes took to pass by reference marks placed every 50 m (4). A 2-D reference system was designed and consisted of a vertical cylindrical post 2 m in height and 0.20 m in diameter. Before the events the reference system was filmed in the center of each lane and in each of the sections of the athletics track; the athletes were later filmed without moving the cameras.

To prevent loss of the instant at which an athlete crossed the references each 50 m, the cameras were grouped into two systems used by an operator. System 1 was formed by cameras 1-3-5 which filmed the start and when the athletes passed the 100 m and 200 m reference marks. System 2 was formed by cameras 2-4 which filmed when the athletes passed the 50 m and 150 m reference marks. Each system consisted of a video recorder (Vídeo-Walkman Sony Hi-8 GV-A500-E) connected to an interval switcher (*Kramer VIS-5X4 Vertical Interval Switcher*) and a time code processor (*Avitel TPR 1040*). The two-time code processors were electronically synchronized. Later, a video capture card (*Matrox RT 2500*) and a video-editing program (*Adobe Premier v 5.0*) were used to mix the recordings from both systems and produce a single film of the full race.

The moment of contact of the anatomical “chest” point of each athlete with the line of the reference system (in their lane on each section of the race) was digitized and the corresponding passing times were recorded. A software program *BioCar* (4) was designed containing the calculation algorithms necessary to get the results for the following variables:

- Interval time for each section: Interval time taken to cover each 50 m section (T_{0-50}; T_{50-100}; $T_{100-150}$; $T_{150-200}$).
- Average velocity in sections: Average value for the velocity over each 50 m section (V_{0-50}; V_{50-100}; $V_{100-150}$; $V_{150-200}$).
- Average velocity for the race (AV).
- Relative average velocity: Percentage of average velocity relative to the maximum velocity reached in the fastest section (50-100 m) ($RAV_{(0-50)-max}$; $RAV_{(100-150)-max}$; $RAV_{(150-200)-max}$). $RAV_{(section)-max} = (V_{section} \times 100)/ V_{50-100}$.

Statistical Analyses

The *Kolmogorov-Smirnov* test was applied to confirm a Gaussian distribution of the results. A *Student's t-test* between two independent groups (outdoor vs. indoor track) was used to compare the variables. The level of statistical significance was set at $P < 0.05$. Analyses were conducted using SPSS version 16.0.

RESULTS

Table 1 show the means ± standard deviations of the interval times in sections and the official time, both for men and women, as well as the statistical significance of differences between the outdoor and indoor tracks.

Table 1 Interval times for each section (s) during the 200 m (women and men) comparing indoors vs outdoors (mean ± s).

Interval times for each section	Women			Men		
	Indoor	Outdoor	*t*	Indoor	Outdoor	*t*
$T_{0–50}$ (s)	*Curve* 6.89 ± 0.12	*Curve* 6.75 ± 004	2.756*	*Curve* 6.18 ± 0.10	*Curve* 6.08 ± 0.09	2.511*
$T_{50–100}$ (s)	*Straight* 5.62 ± 0.07	*Curve* 5.62 ± 0.11	-0.067	*Straight* 4.87 ± 0.11	*Curve* 4.85 ± 0.09	0.653
$T_{100–150}$ (s)	*Curve* 6.03 ± 0.15	*Straight* 5.84 ± 0.06	4.049**	*Curve* 5.26 ± 0.15	*Straight* 5.06 ± 0.07	4.437**
$T_{150–200}$ (s)	*Straight* 6.34 ± 0.19	*Straight* 6.29 ± 0.10	0.812	*Straight* 5.54 ± 0.18	*Straight* 5.45 ± 0.11	1.512
Official Time (s)	24.87 ± 0.45	24.50 ± 0.21	2.608*	21.85 ± 0.50	21.43 ± 0.22	2.679*

Note: * : $P < 0.05$, ** : $P < 0.01$. *Curve sections in shadowing.*

The official time for the race was significantly less outdoors than indoors both in the women's race (24.50 ± 0.21 s vs. 24.87 ± 0.45 s, respectively) and the men's race (21.43

± 0.22 s vs. 21.85 ± 0.50 s, respectively).

However, significant differences were not found in the split times per section in all cases. In both categories, only T_{0-50} and $T_{100-150}$ were significantly shorter outdoors compared with indoors. These differences were of the order of 2.0% and 3.2% respectively, in the women's category and 1.6% and 3.8% in the men.

Figures 1 and 2 present the average velocities for each section for both sexes and both types of track. The same figures present the values for RAV obtained in each section. In both categories, the RAV values in all sections were lower indoors than outdoors. RAV_{0-50} and $RAV_{100-150}$ were 1.7 % and 3.0 % lower, respectively, in the women's category and 0.8 % and 3.1 % lower, respectively, in the men.

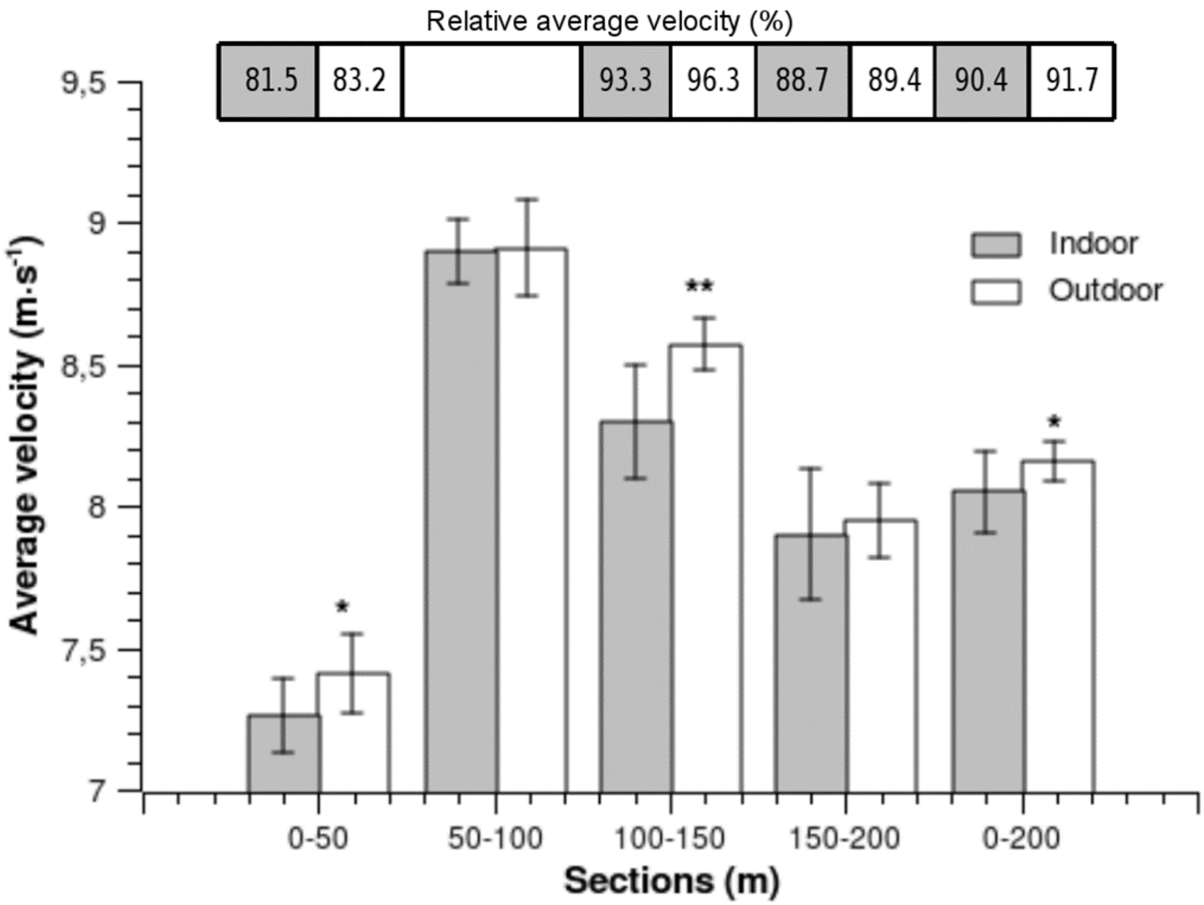

Figure 1 Average velocities (m/s) per 50 m section (women) comparing indoors with outdoors and percentages of average velocities relative to the maximum velocity reached in the fastest section (50-100 m). * : $P < 0.05$, ** : $P < 0.01$.

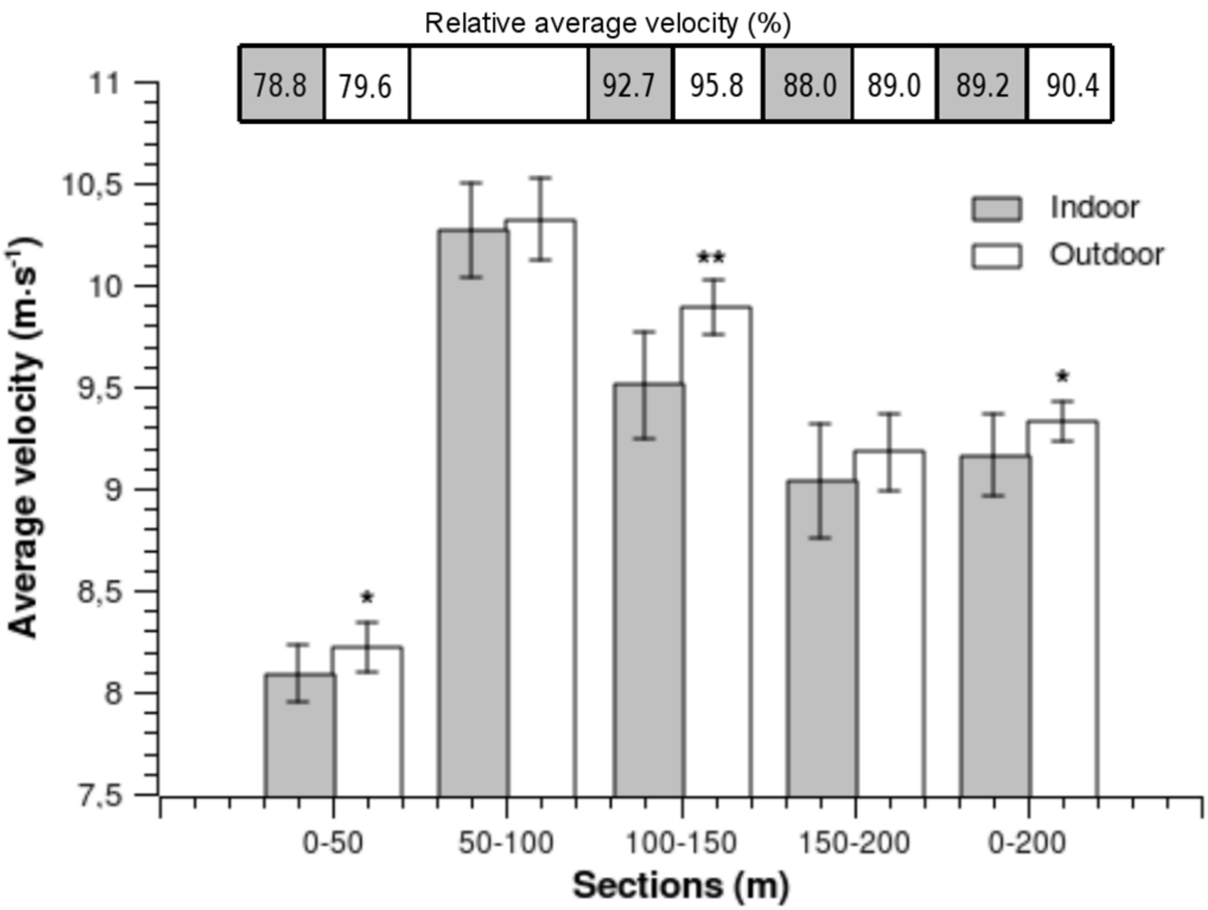

Figure 2 Average velocities (m/s) per 50 m section (men) comparing indoors with outdoors and percentages of average velocities relative to the maximum velocity reached in the fastest section (50-100 m). * : $P < 0.05$, ** : $P < 0.01$.

DISCUSSION

It is widely accepted among experts in athletics that the 200 m event is slower indoors than outdoors, which has been confirmed by the significant difference obtained in the present study between both times. Usherwood and Wilson (17) developed a theoretical model which aimed to predict times for the 200 m indoor from registered outdoor times. This model indicated that indoors athletes run a second slower than outdoors. Although in the results of the present study a significant difference was observed in the times recorded between indoors and outdoors (0.37 s in the women's category and 0.42 s in the men's), this difference was not as large as might be expected from the results of Usherwood and Wilson (17). The possible cause of the difference in the results may be due to the differences in the level of the athletes who participated in the two studies. The athletes participating in the study by Usherwood and Wilson (17) were finalists in the world championships and the Olympics (17); however, the athletes who took part in the present study were finalists in the Spanish national championships.

The interval times for each section into which the race was divided were compared to detect if there were decreases in time in all of them. Surprisingly, differences were only found in the sections in which the athletes mostly ran around the curve on the indoor track, that is from 0-50 m and from 100-150 m. In the 100-150 m section outdoors, the athlete goes from running round a curve to running on the straight while indoors the opposite occurs. This explains the differences found among the values for $RAV_{(100\text{-}150)max}$ outdoors (96,3% in women and 95,8% in men) and those found indoors (93,3% and 92,7% respectively) in both cases with a difference of about 3% between each type of track. In the first case the athletes are beginning to run in a more favorable situation while in the second, as they are again being forced to run round a curve, their velocity decreases. The alternation of curve-straight-curve-straight indoors (Table 1) may limit the acquisition of a more stable velocity pattern by the athletes. They have to change running strategy in just 5 seconds and on two occasions, meanwhile, outdoors this change only happens once. In the section from 150-200 m on both types of tracks the runners are on the straight; outdoors they are continuing to run on the straight but indoors they have gone from a curve to the straight, which is a favorable change.

The finding of differences in the curved sections and not in the straight sections may reinforce the idea of a limiting factor related to the force experienced by the legs in the contact phase (3,5,17). The contact time and therefore the contact time relative to the total stride time, is greater when running round a curve than when running on the straight (5,10,11). However, the 0-50 m section both indoors and outdoors is run round a curve (curve radius ~20 m and ~40 m, respectively) so that the difference in the times recorded could be due to the different radii coinciding with the data reported by Jain (9) and Greene and Monheit (6). This possible explanation also has been suggested by Chang and Kram (3), who studied a group of subjects who ran round curves of different radii. They indicated that vertical GRF decreased as the radius of the curve diminished, and consequently the contact time increased and velocity slowed. Although the radii analyzed by Chang and Kram (3) in their study were smaller (1-6 m) than the ones usually found in indoor tracks (17-22 m), this could be a possible explanation of why it took less time to cover the first 50 m on a curve outdoors than indoors. However, more biomechanical studies are needed on running technique round curves in the future due to the importance that this has for the final result of the competition.

If maximum average velocity is taken as the reference, in women $RAV_{(0-50)-max}$ was 1.7% greater outdoors than indoors while in men it was 0.8% greater. These percentages could be indicative of the differences between the two types of curves, as at the beginning of the event there is no reason to think that they could be due to physiological aspects that could influence the athletes' performance. With regard to the 50-100 m section, no significant differences were found in T_{50-100} in either of the categories in spite of the trajectory being mostly on the straight indoors and on the curve outdoors. This similar time could be due to the fact that the indoor athlete could take more advantage of the favorable straight section and the negative gradient of the banking from the previous curve to equal the velocity of the outdoor athlete despite having started with a slower velocity at the beginning of the interval. The lack of significant differences in $T_{150-200}$ in either of the two categories, having run on the straight in both events, indicates that again the indoor athlete equaled the velocity reached outdoors despite beginning the section at a slower velocity. The loss of velocity with regard to the previous section was less pronounced indoors than outdoors, given that, indoors the athletes went from a curve to the straight favoring them with another negative gradient while outdoors both sections were straight with no gradient. The fact that the study was carried out under competitive conditions is what makes it valuable, as in the literature there are no data on split times for 200 m indoor sprint events. However, this study had some limitations. One is that the groups were not perfectly balanced because not all the athletes ran the same number of times outdoors and indoors at each venue. This study was conducted from the analysis of various competitions providing a high external validity. Using data from competitions has some advantages compared with an experimental study as in these real competitions the athletes had every interest in making the maximum effort and their times were representative of true competitive performances. Moreover, the physical fitness of the runners was considered as ideal for each competition as coaches and runners train conscientiously for every season to reach their optimal level at each important competition. Additionally the variable Relative average velocity is used to compare the speed reduction ratio of each athlete with his or her best personal interval time (reached in 50-100m section) strengthening the statistical analysis. Moreover, RAV is useful for coaches to compare athletes' performances and has not been previously reported in the literature.

Another limitation could be the fact that there may be slight differences in the design of the indoor tracks where the competitions were held with regard to the radii of curvature and the banking of the curve but all of them followed a similar contour. The different weather conditions in the summer season (outdoor) and winter season (indoor) could be ignored. No competitions were held in the rain or with a wind stronger than that allowed in the regulations.

PRACTICAL APPLICATIONS

This study has shown that the indoor curved sections-imposed limitations on the production of velocity by the athlete. When the athlete ran mostly on the curve indoors the velocity was significantly slower than outdoors. In contrast, in indoor straight sections the velocity of the athlete was similar at both venues. This highlights the importance of the curved sections for the race performance. From a training point of view, this means that training should focus on generating greater velocity on the curve. This may allow the athlete to improve in those sections that are crucial in the 200 m indoor race. Moreover, the split-time race analysis may aid coaches and athletes by identifying the section of the race that is the slowest in order to improve the performance. The variable *Relative average velocity* is useful for coaches in order to compare different athletes' performances and the same athlete during different competitive seasons. Finally, the data reported are a valuable reference that could be used by coaches and athletes to compare their results if a similar study is made in training sessions or in competition.

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